3.5 RISK ASSESSMENT: EARTHQUAKE

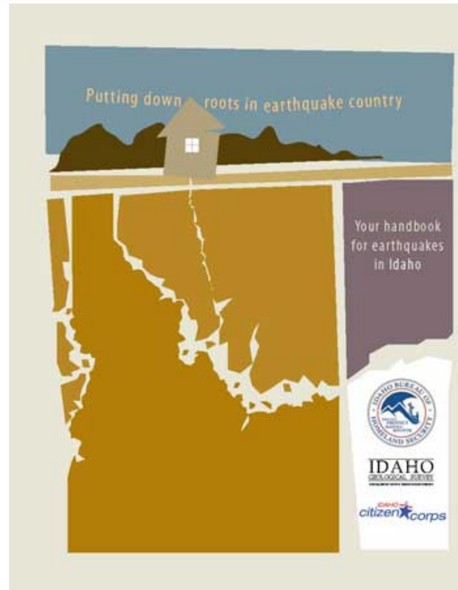
DESCRIPTION

Idaho's earthquakes result from three causes:

- Plate Tectonics
- Crustal Stretching
- Hotspot/Volcanic Activity

The surface of the earth (the crust) is made up of large masses, referred to as tectonic plates. Many of the world's earthquakes result from forces along the margins of these tectonic plates. These earthquakes occur when pressure resulting from these forces is released in a sudden burst of motion. Such earthquakes are produced in coastal California, Oregon, and Washington. The largest of these distant events may be felt in Idaho.

However, most earthquakes in Idaho have origins (the epicenter) far from plate boundaries. Much of the earth's crust in southern and central Idaho has undergone tremendous stretching, resulting in parallel, linear mountains and valleys. This region is called the Basin and Range and extends into the adjoining States of Montana, Utah, Wyoming, and Nevada. Basin and Range stretching is continuing today. Earthquakes from these crustal movements can also cause severe ground shaking in Idaho.



An excellent source of additional information on the earthquake hazard in Idaho is the publication *Putting Down Roots in Earthquake Country*

http://www.idahogeology.org/uploads/Putting_Down_Roots_3_19_11.pdf

Finally, Idaho earthquakes may be associated with magmatic activity. This activity is associated with the "Yellowstone Hotspot." The hotspot is a conduit carrying molten rock (magma) from deep within the earth into the crust. Pressures within the hotspot zone lead to earthquakes. Although there are currently no surface releases of magma through volcanoes or volcanic vents, the hotspot is very seismically active. Dozens of small earthquakes are recorded in the Yellowstone region each month.

Earthquake Mechanics

Regardless of the source of the earthquake, the associated energy travels in waves radiating outward from the point of release. When these waves travel along the surface, the ground shakes and rolls, fractures form, and water waves may be generated. Earthquakes generally last a matter of seconds, but the waves will travel around the world in a matter of minutes and may cause damage elsewhere.

Breaks in the crust associated with seismic activity are known as "faults" and are classified as either active or inactive. Faults may be expressed on the surface by sharp cliffs or scarps or may be buried below surface deposits.

"Foreshocks" may occur months or minutes before the actual onset of an earthquake. Although smaller than the main shock, some foreshocks are large, damaging earthquakes. "Aftershocks," which range from minor to major, may occur for months after the main earthquake. In some cases, strong aftershocks may cause significant additional damage, especially if the initial earthquake affected emergency management and response functions or weakened structures.

Idaho has active faults that have produced a number of historic earthquakes. These faults are classified as normal faults and were produced by Basin and Range stretching. The faults extend into the crust at dips of about 60 to 70 degrees. Earthquakes along the faults occur at depths of less than 35 kilometers. Seismologists term these shallow earthquakes.

Factors Contributing to Damage

The damage associated with each earthquake is subject to four primary variables:

- The nature of the seismic activity
- The composition of the underlying geology and soils
- The level and quality of development of the area struck by the earthquake
- The time of day

Seismic Activity: The properties of earthquakes vary greatly from event to event. Some seismic activity is localized (a small point of energy release), while other activity is widespread (e.g., a major fault letting loose all at once). Earthquakes can be very brief (only a few seconds) or last for a minute or more. The depth of release and type of seismic waves generated also play roles in the nature and location of damage; shallow quakes will hit the area close to the epicenter harder, but tend to be felt across a smaller region than deep earthquakes.

Geology and Soils: The surface geology and soils of an area influence the propagation (conduction) of seismic waves and how strongly the energy is felt. Generally, stable areas (e.g., solid bedrock) experience less destructive shaking than unstable areas (e.g., fill soils). The siting of a community or even individual buildings plays a strong role in the nature and extent of damage from an event.

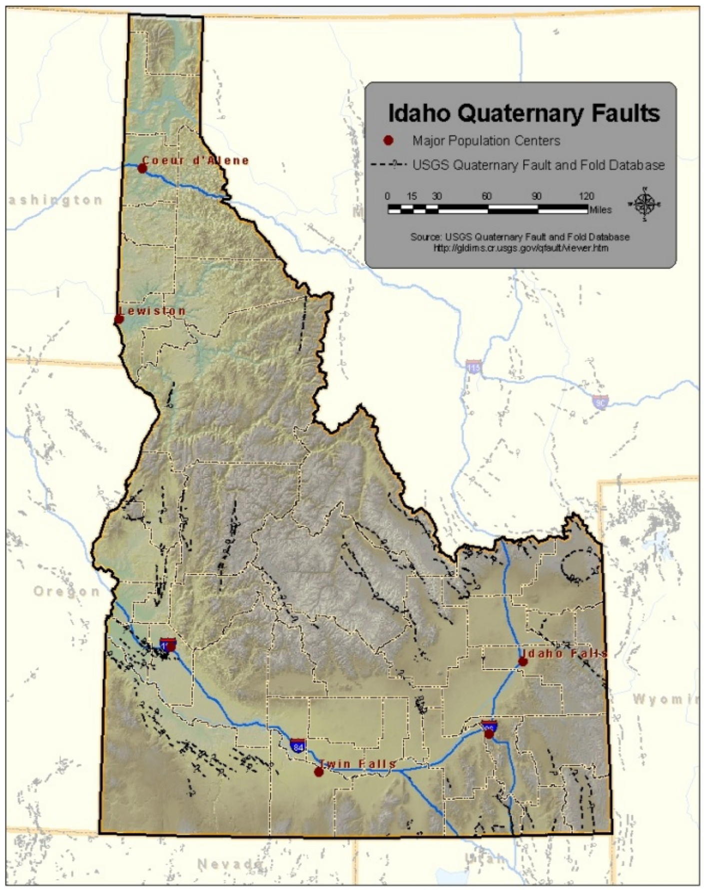
Development: A small earthquake in the center of a major city can have far greater consequences than a major event in a thinly populated place. The two major Idaho earthquakes, Hebgen Lake (1959) and Borah Peak (1983) were very strong but occurred in isolated areas with small populations. The damage, compared to that of earthquakes of similar magnitude in heavily populated areas, was relatively light.

Time of Day: The time of day that an event occurs controls the distribution of the population in an affected area. On work days, the majority of the community will transition between work or school and home, so the time of day will affect the location of the population. The relative seismic vulnerability of each location can strongly influence the loss of life and injury resulting from an event.

Types of Damage

While damage can occur by movement at the fault, most damage from earthquake events is the result of shaking. Shaking also produces a number of phenomena that can generate additional damage:

- Ground displacement
- Landslides and avalanches
- Liquefaction and subsidence
- Seiches



Map 3.5.A: Quaternary Faults in Idaho / Source: USGS

Shaking: In minor events, objects fall from shelves and dishes are rattled. In major events, large structures may be torn apart by the forces of the seismic waves. In all but the largest quakes, structural damage is generally limited to older structures that are poorly maintained, constructed, or designed. Unreinforced masonry buildings and wood frame homes not anchored to their foundations are typical victims. In areas of severe seismic shaking hazard, Intensity VII or higher can be experienced even on solid bedrock. In these areas, older buildings especially are at significant risk.

Loose or poorly secured objects also pose a significant hazard when they are loosened or dropped by shaking. These "non-structural falling hazard" objects include bookcases, heavy wall hangings, and building facades. Home water heaters pose a special risk, due to their tendency to start fires when they topple over and rupture gas lines. Crumbling chimneys may also be responsible for injuries and property damage.

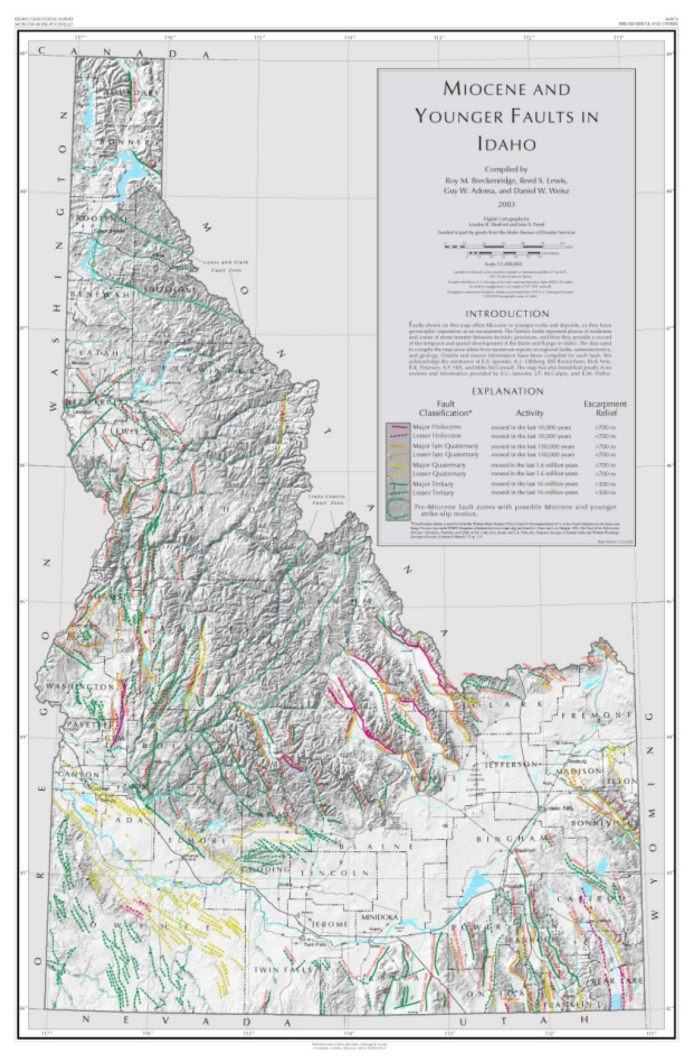
Dam and bridge failures are significant risks during stronger earthquake events, and may result in considerable property damage and loss of life.

Ground Displacement: Often, the most dramatic evidence of an earthquake is the displacement of the ground along a fault line. Map 3.5.A shows the locations of these faults that occurred during the Quaternary Period. Map 3.5.B is a similar map showing those faults occurring over a longer time period, beginning in the Miocene Period through current day. The Borah Peak event created a surface fault nearly 22 miles long and generated a scarp face up to 9 feet high in certain locations. Utility lines and roads may be disrupted, but damage directly attributable to ground displacement is generally limited. In rare instances, structure located directly on the fault line may be destroyed by the displacement.

Landslides and Avalanches: Even small earthquake events can cause landslides. Rock falls are common as unstable material on steep slopes is shaken loose, but significant landslides or even debris flows can be generated if conditions are ripe. Roads may be blocked by landslide activity, hampering response and recovery operations. Avalanches are possible when the snowpack is sufficient.

Liquefaction and Subsidence: Soils may liquefy and/or subside when impacted by the seismic waves. Fill and previously saturated soils are especially at risk. The failure of the soils can lead to widespread structural damage. The oscillation and failure of the soils may result in increased water flow and/or failure of wells, as the subsurface flows are disrupted and sometimes permanently altered. Increased flows may be dramatic, resulting in geyser-like water spouts and/or flash floods. Similarly, septic systems may be damaged, creating both inconvenience and health concerns.

Seiches: Seismic waves may rock an enclosed body of water (e.g., a lake or reservoir), creating an oscillating wave referred to as a "seiche." Although not a common cause of damage in past Idaho earthquakes, there is a potential for large, forceful waves similar to a tsunami (tidal wave) to be generated on the large lakes of the State. Such a wave would be a hazard to shoreline development and pose a significant risk on dam-created reservoirs. A seiche could either overtop or damage a dam, leading to flash flooding downstream.



Map 3.5.B: Miocene and Younger Faults in Idaho / Source: Idaho Geological Survey

Further, such events may create the right conditions for a hydrothermal explosion. Yellowstone National Park and the adjacent Snake River plain have experienced 18 large hydrothermal explosions over the past 14,000 years, according to the United States Geological Survey (USGS). This is the most frequent type of explosion in the park. Three areas in Yellowstone; Mary Bay, Turbid Lake, and Indian Pond were apparently formed by large hydrothermal explosions. Mary Bay is nearly one mile across. The following URL provides a link to a recent USGS report regarding hydrothermal hazards in Yellowstone [http://pubs.usgs.gov/of/2007/1071]

LOCATION, EXTENT, AND MAGNITUDE

As indicated in the previous sections, just as there are multiple sources of seismic activity in Idaho, the location of seismic activity varies as well. Many earthquakes occur along faults; however, Idaho has a considerable number of unmapped faults and many small to moderate earthquakes do not occur on faults. Map 3.5.A shows the older Quaternary faults (<1.6 million years ago). The USGS normally ignores these faults unless there is recognized slip in the fault. Map 3.5.B shows the faults in Map 3.5.A plus older, inactive faults (which correlates to no slippage in 10,000 to 15,000 years).

Map 3.5.N, at the end of this section, shows the areas of Idaho that are most vulnerable to seismic risk, based on the potential damages. These potential damage classifications are based upon spectral acceleration (SA) values, which equate to the acceleration experienced by a structure during a seismic event. This map conveys the fact that damaging earthquakes can happen anywhere in Idaho, but the area's most likely to experience heavy damage occur in the southeast corner of the state, portions of the northern panhandle, and a large region that stretches across the middle of the State. Map 3.5.M, also at the end of this section, also presents the past hypocenter locations of past earthquakes. This distribution seems to closely mirror the spatial pattern seen in Map 3.5.N.

The important fact regarding Idaho seismicity is that most Idaho earthquakes are not associated with known faults. This is easily seen when plots of recorded seismicity are compared with fault maps. Many, if not most, Idaho earthquakes are not on mapped faults. One explanation for this is Idaho's poor seismic monitoring. A low density of seismic monitoring stations, as exists in Idaho, would result in inherently poor earthquake location precision. Another possibility is that a number of unknown faults exist and that small earthquakes are occurring away from faults. However, large earthquakes generally occur on large, well-known faults.

The Yellowstone Tectonic Parabola is a region of earthquakes, active faulting, and topographic uplift surrounding the eastern Snake River Plain. This plain was formed as the North American continent passed over a stationary plume or "hotspot" of hot rock rising from the earth's mantle. The pattern of earthquake activity in eastern and central Idaho seems to be related to interactions between the hotspot and Basin and Range extension.

Geologists divide the region into five tectonic belts based on historical earthquake activity and the age and amount of movement on prehistoric faults. Within the Snake River Plain, earthquake activity is very low. Earthquake activity increases and faults become younger away from the plain, culminating in a band of youthful, active faults that forms the tectonic parabola on the east. Faulting and earthquakes in western and northern Idaho are not well-explained by the Yellowstone tectonic parabola model.

The extent and magnitude of earthquakes are measured in two ways:

- Magnitude (as measured by the Richter Scale) – measures the energy that is released
- Intensity (as measured by the Modified Mercalli Intensity Scale [MM]) – measures physical effects

Magnitude is calculated by seismologists from seismograph readings and is most useful to scientists comparing the power of earthquakes. Magnitude is often described using the Richter scale. An earthquake of Magnitude 2.5 or less is usually not felt. Dishes rattling and china shaking occur at Magnitude 3.0, and magnitudes greater than 6.5 are devastating events when the earthquake strikes in or near a populated area.

The Modified Mercalli Intensity Scale is a subjective description of the physical effects of the shaking, based on observations at the event site. The damage from earthquake shaking is affected by several factors, such as distance from the epicenter and local geology and soils. On the Modified Mercalli Intensity Scale, a value of I is the least intense motion, and XII is the greatest ground shaking. Unlike magnitude, intensity can vary from place to place and is evaluated from people's reactions to events and the visible damage to man-made structures. The following is a brief explanation of the Modified Mercalli Scale:

I. Not felt except by a very few under especially favorable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Another way to measure intensity is through ground acceleration. This is expressed as either "peak ground acceleration" (PGA) or "spectral acceleration" (SA) expressed relative to the acceleration of gravity (g) and determined by seismographic instruments. While Mercalli (MM) and PGA intensities are arrived at differently, they correlate reasonably well. SA is the basis for the vulnerability presented in Map 3.5.N. What is important here is that ground and spectral accelerations are quantitative measures, while MM is qualitative. Engineers and others interested in designing earthquake-resistant structures need the quantitative information, but a great deal of useful data can quickly be gathered by untrained people with the qualitative MM scale. Both PGA and SA have units of acceleration of gravity (or percent of acceleration of gravity).

PGA and SA are further defined at: http://earthquake.usgs.gov/learn/glossary/?term=spectral%20acceleration%20%28SA%29

Figure 3.5.C, below, correlates PGA and MM. Additional information can be found on the USGS website (http://earthquake.usgs.gov/earthquakes/shakemap/background.php).

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 3.5.C: Correlation between Ground Acceleration and Intensity / Source: United States Geological

Geologic evidence shows that movement on the faults in and around Idaho can cause earthquakes of magnitude 6.5 to 7.5, with potentially catastrophic effects.

PAST OCCURRENCE

Earthquakes in Idaho are common; in fact, during a one-week period ending on September 23, 2010, Idaho experienced four earthquakes, all with a magnitude of less than 2. Idaho experiences hundreds of earthquakes every year, but most are too small to feel. On average Idaho experiences shaking strong enough to damage chimneys every 10 years and a more significant event about every 20 years.
Table 3.5.D provides a summary of significant Idaho earthquakes throughout recent history. From 1872 through the end of 2012, over 3,000 seismic events have been recorded in the State of Idaho. Map 3.5.M, at the end of this section, illustrates past earthquake occurrences in Idaho.

TABLE 3.5.D: Significant Idaho Earthquakes

1872	7.4	Lake Chelan, WA	Largest quake in Washington State; felt strongly in North Idaho
1884	6	Bear Lake Valley	Considerable damage to houses in Paris, ID
1905	6	SW Idaho or NE Nevada	Considerable damage at Shoshone, ID
1913	5	Adams County	Broke windows and dishes
1914	6	Utah-Idaho State line	Intensity VII; between Ogden, UT and Montpelier, ID
1915	7.75	Pleasant Valley, NV	Considerable damage in SW Idaho, 100 miles from epicenter
1916	6	North of Boise	Boise residents rushed into the street, chimneys fell
1918	5	North Idaho	Widely felt near Sandpoint
1925	6.6	SW Montana	Felt throughout Idaho
1926	4	North Idaho	Felt at Avery and Wallace
1927	5	Connor Creek	On Idaho-Oregon border, west of Cascade
1934	6.6	Hansel Valley, UT	Largest Utah event on record; 20 miles south of Idaho border; 2 fatalities
1935	6.25	Helena, MT	Extensive damage; multiple large events felt throughout Idaho; 4 fatalities
1936	6.4	Walla Walla, WA	Damaging earthquake; widely felt in Idaho
1942	5	Sandpoint area	Cracked plaster; rock fell onto railroad tracks

TABLE 3.5.D: Significant Idaho Earthquakes			
1944	6	Central Idaho	Knocked people to ground in Custer County
1944	4	Lewiston area	Widely felt in northern Idaho
1945	6	Central Idaho	Epicenter near Clayton; slight damage in Idaho City and Weiser
1947	6.25	Southwest Montana	Epicenter in Gravelly range, 10 miles north of Idaho border
1947	5	Central Idaho?	Several large cracks formed in a well-constructed brick building
1959	7.3	Hebgen Lake, MT	Major event, extensive fault scarps; 20 miles from Idaho; 29 fatalities
1960	5	Soda Springs	Foundations and plaster cracked
1962	5.7	Cache valley	Heavily damaged older buildings
1963	5	Clayton	Plaster cracked and windows broken
1969	5	Ketchum	Cement floors cracked
1975	6.1	NW Yellowstone	Widely felt in Yellowstone region
1975	6.1	Pocatello Valley	Some 520 homes damaged in Ridgedale and Malad City
1977	4.5	Cascade	Drywall, foundations cracked; ceiling beams separated
1978	4	Flathead Lake, MT	Felt in NW Idaho
1983	6.9	Borah Peak	Major event, 21-mile surface scarp; 11 buildings destroyed, 2 fatalities
1984	5	Challis	Largest of many Borah Peak aftershocks
1988	4.1	Cooper Pass	Montana border NE of Mullan
1994	5.9	Draney Peak	Remote area of Wyoming border; 1 injury from falling flower pot
1994	3.5	Avery area	Rare North Idaho event centered near Hoyt Mountain
1999	5.3	Lima, MT	In Red Rock valley, just north of Idaho border
2001	4	Spokane, WA	At least 75 felt events at shallow depth beneath the city
2005	5.6	Dillon, MT	Felt across Idaho

TABLE 3.5.D: Significant Idaho Earthquakes			
2005	4	Alpha Swarm	Four events of M4, thousands of smaller tremors south of Cascade
2008	6.0	Wells, NV	Felt strongly throughout southern Idaho
2010	4.6	Randolph, UT	Shaking experienced in Idaho, Wyoming, and Utah
2010	4.8	Jackson Hole, WY	Shaking lasted ~10 seconds, toppled lamps in Jackson, shaking experienced in Idaho.
			***Magnitudes without decimals are approximate / Source: United States Geological Survey**

Hotspot-related seismic activity is confined to the Yellowstone region on the eastern border of the State. Dozens of small earthquakes (less than Magnitude 3.0) occur here each month, with larger events occurring about once a month. Fault-related seismic activity occurs throughout the State but is concentrated in the central mountains and in the southeast corner. From 2007-2010, earthquakes ranging from 2.0 – 3.8 have been felt annually in southeastern Idaho originating from north Utah along the Wasatch Fault zone[1]. Idaho has a substantial number of known and suspected active faults. However, USGS uses only seven faults to compute the probabilistic seismic hazard maps for Idaho. Nonetheless, when identified, these faults can be useful for projecting future seismic activity.

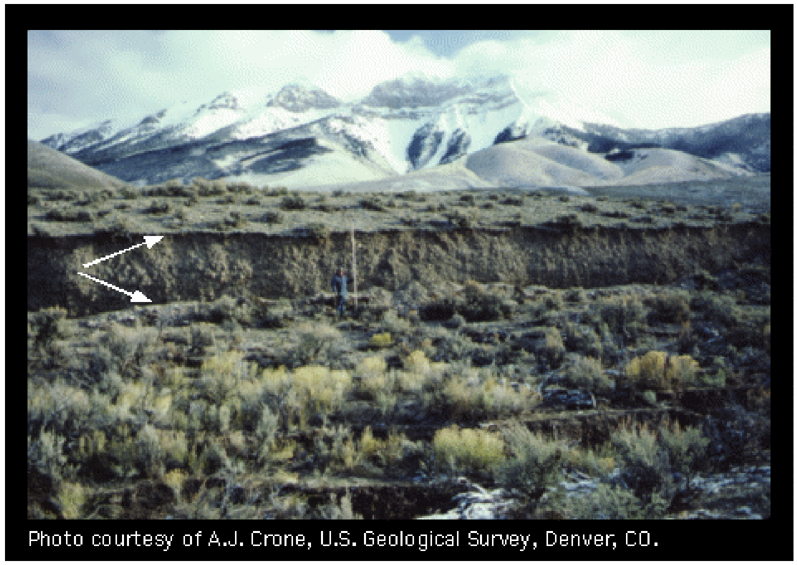
Hebgen Lake, 1959

The Hebgen Lake earthquake (August 18, 1959) originated in Montana but was felt and caused considerable damage in Idaho. The Magnitude 7.3 event generated Intensity X shaking, killed 28 people as a result of an enormous landslide, formed "Quake Lake," and did $11 million damage to roads and timber. Many campers in the Yellowstone area were trapped for days (eventually rescued with the assistance of smoke jumpers and helicopters), and a fishing lodge dropped whole into a lake. There were six aftershocks of Magnitude 5.5 or greater within one day, and one of Magnitude 5.8 in 1964. The initial earthquake was felt in an area of over 450,000 square miles.

Hebgen Lake Earthquake / Source: Deseret News

[1] Source: Oneida County Multi-Jurisdictional All Hazard Mitigation Plan

In Idaho, Intensity VII was experienced in the areas of Big Springs, Island Park, and Henry's Lake. Big Springs increased its flow 15 percent and became rusty red colored, and wells in the Island Park area remained muddy for weeks. A man was knocked down at Edward's Lodge, and guests at Mack's Inn experienced hysteria. There was considerable damage to buildings in the Henry's Lake area. Trees swayed violently, breaking some roots, and cars jumped up and down. Chimneys fell, and a 7-foot-thick rock-and-concrete dock cracked.



Borah Peak Earthquake / Source: USGS

Borah Peak, 1983

The Borah Peak earthquake (October 28, 1983) was the largest ever recorded in Idaho, both in magnitude and in the amount of property damage, ($29.4M - in 2012 dollars). With a magnitude of 6.9, it was among the largest earthquakes to hit the State since the 1959 Hebgen Lake event. The epicenter was in the Barton Flats area, approximately 10 miles northwest of Mackay and 30 miles southeast of Challis. There have been a number of California earthquakes larger than this: 1999 Hector Mine (7.1), 1992 Landers (7.3), 1992 Cape Mendocino (7.2), 1989 Loma Prieta (6.9), and 1980 Humboldt (7.2).

The maximum observed intensity was IX (based on surface faulting), and the earthquake was felt in an area of over 330,000 square miles. Four aftershocks of Magnitude 5.5 or greater were recorded within 1 year, and numerous more have occurred to date. Map 3.5.E on the following page shows the shaking in MM Intensity scale units.

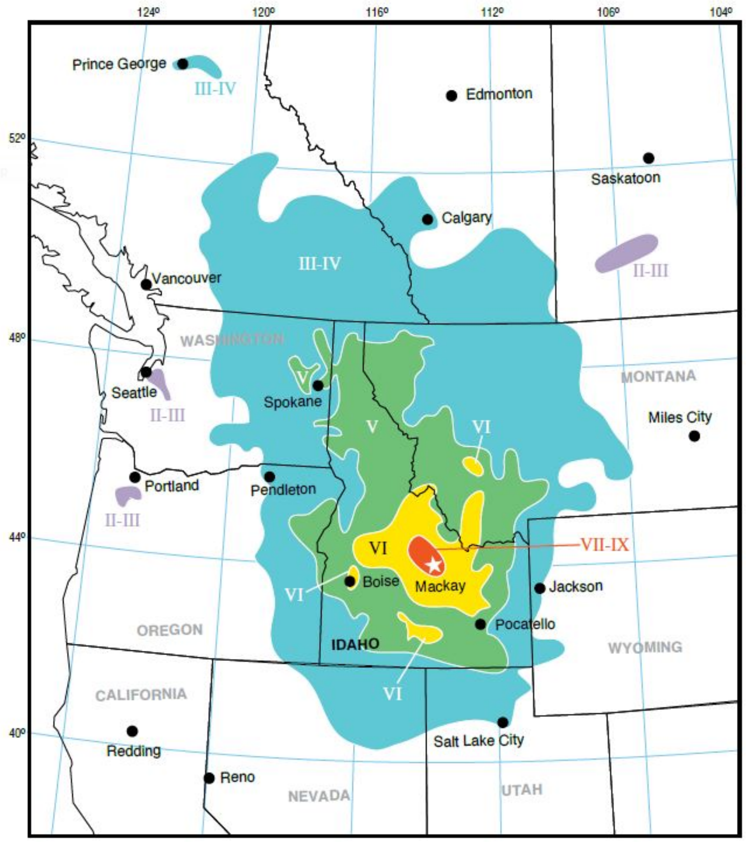
The event caused two deaths in Challis (both school age children) and several minor injuries. There was an estimated $12.5 million in damage in the Challis-Mackay area, affecting sewer and water systems, roads, other public facilities, and personal property. The facilities of an irrigation company and a fish hatchery also experienced extensive damage.

Although damage occurred as far away as Boise, the most severe property damage occurred in the towns of Challis and Mackay. Eleven commercial buildings, 39 private houses, and one school sustained major damage, and 200 houses sustained minor to moderate damage. Most of the damaged commercial buildings were of masonry construction, including brick, concrete block, or stone. The majority of the residential chimneys were cracked or twisted, or collapsed.

Significant ground displacement produced a 20-mile-long zone of fresh scarps and ground breakage in the Lost River Range. Displacement along the fault ranged from less than 1.5 feet to 9 feet.

Other geologic effects included landslides and rock falls, flow changes in springs, and fluctuations in water levels. A temporary lake was formed by the rising water table south of Dickey, and widespread flooding occurred in the Warm Springs Creek area.

The event resulted in State and Federal disaster declarations (designated *DR-694*). The declaration provided Public Assistance and Individual Assistance for Custer County, Individual Assistance for Butte County, and aid to schools in Butte and Gooding Counties.



Map 3.5.E: Borah Peak Intensity / Source: USGS

Valley County Earthquake Swarm, 2005

Between September and December 2005, thousands of small, very shallow earthquakes occurred near the community of Alpha in Valley County. These events, five with magnitudes as high as 4, were centered about 16 kilometers south of Cascade, in the vicinity of Clear Creek. The Idaho Geological Survey and BHS arranged for the deployment of a temporary seismic array to study the swarm. However, a seismologist from Boise State University reported a year later that, in his opinion, the swarm was incorrectly mapped due to “poor seismographic coverage.” (Cite: Jim Zollweg, “The 2005 Alpha, Idaho Earthquake Swarm: A Preliminary Report,” March 31, 2006.)

Earthquake Catastrophes and Fatalities Projected to Rise in Populous 21st Century

MENLO PARK, Calif. —Predicted population increases in this century can be expected to translate into more earthquakes with very large death tolls and more people dying during earthquakes than ever before, according to a newly published study led by U.S. Geological Survey engineering geologist Thomas L. Holzer.

Holzer and his USGS coauthor James Savage studied earthquakes with death tolls of more than 50,000, which they define as catastrophic, and reported global death tolls from roughly 1500 A.D. to the present. Comparing those events to estimates of world population, they found that the number of catastrophic earthquakes has increased as population has grown. After statistically correlating the number of catastrophic earthquakes in each century with world population, they were able to use new (2011) 21st-century population projections by the United Nations to project that approximately 21 catastrophic earthquakes will occur in the 21st century, a tripling of the seven that occurred in the 20th century. They also predict that total deaths in the century could more than double to approximately 3.5 million people if world population grows to 10.1 billion by 2100 from 6.1 billion in 2000.

"This prediction need not be a prophesy: the National Earthquake Hazard Reduction Program (NEHRP) in the U.S. can be a model for how science can inform engineering designs that are adopted into life-saving building codes in earthquake-prone regions," said USGS Associate Director for Natural Hazards David Applegate. "I also cannot stress enough the value of educated citizens — those who understand the natural hazards of this planet and are empowered to take action to reduce their risk."

Four catastrophic earthquakes have already struck since the beginning of the 21st century, including the 2004 Sumatra-Andaman earthquake (and tsunami) and 2010 Haiti earthquake that each may have killed over 200,000 people. The study explains this increase in lethal earthquakes. It is not that we are having more earthquakes; it is that more people are living in seismically vulnerable buildings in the world's earthquake zones.

Holzer's study underscores the need to build residential and commercial structures that will not collapse and kill people during earthquake shaking.

"Without a significant increase in seismic retrofitting and seismic-resistant construction in earthquake hazard zones at a global scale, the number of catastrophic earthquakes and earthquake fatalities will continue to increase and our predictions are likely to be fulfilled," Holzer said.

Although little damage was reported, many of the events were felt locally. Most of the Alpha swarm appears to have occurred along a previously unidentified fault that separates Long Valley to the north from Round Valley to the south. The latest of the five events may have been triggered by stress released from the other earthquakes. This event occurred several kilometers northwest of the others and was consistent with normal faulting on the Long Valley fault, one of the major Quaternary faults in Idaho.

Wells, Nevada Earthquake, 2008

The Wells, Nevada earthquake was felt in southern Idaho, and significant shaking was reported. On February 21, 2008, the northern Nevada town of Wells was struck by a 6.0 Magnitude earthquake resulting from a seismic event on a previously unmapped fault. Half of the non-residential buildings in Wells were damaged, and 10 of those sustained severe damage. The event appeared to occur almost instantaneously and caused nearly $9 million in damages. The community of Wells was severely disrupted for months and, due mostly to the lack of a presidential declaration and subsequent Federal aid, most of the heavily damaged buildings in the older part of town remain in ruins. The circumstances of this event could easily be replayed in many areas of Idaho.

Yellowstone Earthquake Swarm, 2010

In January and again in April 2010, a swarm of earthquakes occurred about 10 miles northwest of the Old Faithful area on the northwestern edge of the Yellowstone Caldera. Swarms have occurred in this area several times over the past 30 years; however, this swarm became the second largest ever recorded at Yellowstone –both longer (in time) and including more earthquakes than the December 2008-January 2009 swarm. As of September 2010, earthquake activity had returned to near background levels. To complicate matters, the plate beneath Yellowstone Lake ceased its tilting motion. Seismologists are uncertain as to whether or not this is a good thing. Damage from prehistoric caldera events was massive, and a similar event in this day and age would be cataclysmic.

Because of recent Hollywood depictions of a Yellowstone super-volcano and despite the location of Yellowstone in neighboring Wyoming, a comment regarding geological and seismic potentials is warranted. Regarding a super-volcano event, the USGS states in its Open-File Report 2007-1071, "the probability of a forth large caldera-forming event at Yellowstone can be considered to be less than 1 in a million..." The relatively greater hazards are hydrothermal explosions of which 26 have occurred in the past 30 years.

FUTURE OCCURRENCE

Currently, there are no realistic methods to predict earthquakes. According to the Idaho State seismologist, no studies, past or present, could create anything more than the general probabilities currently available. The past rate of occurrence is a modest predictor of future occurrence. One possible exception would be increased volcanic activity related to the Yellowstone hotspot. If that occurs, seismic activity would also be likely to increase. Nonetheless, the assessment of seismic risk is significantly impaired by 1) a lack of fault characterization data for Idaho's mapped faults, 2) limited NEHRP soil and liquefaction susceptibility maps, and 3) extremely limited seismic monitoring throughout Idaho.

RELATIONSHIPS TO OTHER HAZARDS

Earthquakes do have the ability to initiate and impact a number of other hazards, both natural and human-caused. Avalanches and landslides are two hazards that can be initiated by a seismic event. Dams, levees, and canals are also at risk of damages that could be caused by an earthquake or the resulting seiches. These damages have the possibility of causing the structures to fail, thereby producing a dam/levee/canal failure hazard event. Uplift and displacement from a major seismic event could also result in the re-routing of existing streams, the result of which could be flooding. The damages that could result from an earthquake would certainly have an opportunity to initiate fires.

From a human-caused perspective, a worst case earthquake scenario could spawn any of the hazards discussed in this plan. A less intense seismic release could still disrupt power and communication systems, possibly leading to smaller scale energy shortages or cyber disruptions.

ENVIRONMENTAL IMPACTS

The environmental impacts of earthquakes are highly dependent on the location of the quake. For example, in mountainous regions, earthquakes and aftershocks can cause landslides and land deformation and result in infrastructure damage. Microwave communication towers could be knocked out of alignment. In areas of human development, damaged infrastructure such as sewage systems and pipelines can result in large releases of harmful substances into the environment. Quickly and successfully eliminating waste and debris after an earthquake will lower the amount of resulting disease and contamination to the environment. The failure of dams, levees, and canals after an earthquake could cause a rapid and possibly catastrophic flood event.

DEVELOPMENT TREND IMPACTS

Some counties in the Northeast and Southeast, such as Jefferson, Teton, and Bonneville, have high growth rates and face significant seismic threat. In such areas, it can be predicted that an increased amount of housing stock and developed area will be at risk. However, seismic codes may mitigate the potential losses of life, injuries, and property damage.

Seismic building codes increase building integrity and help ensure the future safety of communities. These codes are designed to protect lives, but not to ensure that buildings are undamaged or usable after an earthquake. Seismic codes are intended to protect people inside buildings by preventing collapse and allowing safe evacuation. Structures built according to the current code should be undamaged in minor earthquakes, resist moderate earthquakes without significant structural damage, and resist severe earthquakes without collapse. In Idaho, seismic codes made substantial improvements in construction as early as the mid-1970s. Buildings constructed prior to this time may be seismically unsafe. However, buildings constructed in the 1980s would not be as seismically safe as buildings constructed under today's seismic codes. To keep up with the latest progressions in seismic design, building codes are revised every three years to incorporate new data findings and knowledge.

CRITICAL INFRASTRUCTURE AND STATE FACILITY IMPACTS

Major highways, railways, and power/communication transmission lines would be some of the State assets with the potential to be impacted by a seismic event. State facilities that were constructed prior to the mid-1970, which have not yet been seismically retrofitted, would be the structures most vulnerable to the negative impacts arising from a seismic event. As mentioned in the previous section though, even those facilities constructed under building codes that reflected increased attention to seismicity could still be vulnerable to earthquakes. This is due to the fact that data and scientific analysis relating to earthquakes are continually being improved and enhanced. Therefore a structure built to 1980's construction codes would have increased vulnerability as compared to a similar structure built today.

As part of the 2010 Plan update, one action that the State identified was the need to collect improved and up-to-date State-owned facility and infrastructure data in a geospatial format. As of the writing of the 2013 Plan update, this action is still considered in progress, although great strides have been made.

The State Chief Information Officer (CIO) is currently working towards the realization of a State-owned facilities and infrastructure geodatabase. This on-going process has been slowed by recent budget shortfalls in addition to inconsistent data holdings across many of the State's Agencies. Once available, this database will enable for a more in-depth review of State-owned facilities and infrastructure, as it relates to both vulnerabilities to hazards and the associated loss estimations.

VULNERABILITY ASSESSMENT AND LOSS ESTIMATION

Statewide Analysis

All of Idaho's counties have a low, moderate, or high seismic hazard vulnerability, and 38 counties contain areas of high vulnerability (see Map 3.5.N at the end of this chapter). The majority of the State's population is concentrated in areas of high seismic risk, either along faults that define the margins of mountain ranges or in seismically active mountainous areas. Moreover, seismic hazard assessments in Idaho are made more complicated because most of Idaho's earthquakes are not associated with known faults. As such, lifelines (e.g., utilities and transportation routes) and critical facilities (e.g., dams, government, military, and research installations) are at risk in varying degrees that are not easily classified, due mainly to inadequate seismic monitoring. It is important to note the difference between hazard and risk in this plan. To use an example, the eastern Idaho town of Driggs is in a high seismic hazard zone as shown by the USGS 2008 Probabilistic Seismic Hazard map. This is due to its proximity to major active faults and the amount of recorded seismicity near it. Boise, on the other hand, has a lower seismic hazard as shown on the same map. It is farther from major high-slip rate faults and lacks much recorded seismicity. However, Boise may have a higher risk from earthquakes because it has a much higher population and more structures and critical infrastructure than does Driggs.

Source: ThinkStock.com

The United States Geological Survey (USGS) has produced Probabilistic Seismic Hazard Maps, a series of maps and GIS datasets that define the seismic hazard of earthquakes. Advantages of using these maps are: 1) maps are produced using a carefully documented protocol with best available scientific information; 2) maps are produced for the entire USA, permitting valid comparisons between political jurisdictions; 3) maps are incorporated into the International Building Code (IBC) and International Residential Code (IRC); and 4) maps updated every 6 years.

The 2006 IRC refers only to 0.2-second SA with 2% probability of exceedence in 50 years. The reasoning behind this is because it is focused on short periods typical of residences. The non-Hazus-based risk assessment presented next utilizes this same data used by the IRC. SA values, which correlate to the acceleration experienced by a structure during a seismic event, have been equated to defined potential damage classifications by the USGS. These classification zones of potential damages are shown on Map 3.5.N at the end of this chapter.

Using these damage estimate zones, vulnerability analysis was performed on the ICRMP locally-owned facilities data. Table 3.5.F below presents the results of that analysis, showing those facilities that were exposed to Heavy Potential Damages. This table, summarized at the BHS Regional level, includes counts of structures considered to be most vulnerable to the threat of an earthquake, in addition to the associated building values and building content values. Map 3.5.N at the end of this chapter presents this same information, although it is difficult to visually present structure-related information on a State-wide map. Additional details regarding the ICRMP data can be found in the introductory section of this chapter, Section 3.0.

The analysis below shows that all BHS Regions, except the North Central, have local jurisdictionally-owned structures in the defined Heavy Potential Damage areas. Those most vulnerable include the Northeast and Southeast Regions, with 92% and 88% of the facilities, respectively, in these high hazard zones. Statewide, those structures in the zones most vulnerable to earthquake equate to 31.6% of the overall inventory, which is approximately $1.46 billion in combined building values.

TABLE 3.5.F	In Heavy Potential Damage Area			Statewide		
	Number of Facilities	Building Value ($M)	Building & Contents Value ($M)	Number of Facilities	Building Value ($M)	Building & Contents Value ($M)
Central	177	$108	$129	1,570	$815	$972
North Central	0	$0	$0	756	$248	$289
Northeast	913	$459	$565	994	$474	$580
Northern	391	$139	$174	1,334	$669	$850
Southeast	1,120	$364	$476	1,270	$381	$488
Southwest	426	$91	$119	2,513	$1,090	$1,310
TOTALS	**3,027**	**$1,161**	**$1,463**	**8,437**	**$3,677**	**$4,489**

The intensity of ground shaking during an earthquake varies according to the nature of near-surface materials. For example, shaking intensity is generally greater in areas underlain by unconsolidated materials than in those underlain by firm bedrock. Also, areas with high water tables that are underlain by geologically young, sandy sediments or artificial fills that have not been properly compacted can experience liquefaction during earthquakes. Geologic mapping and specialized geotechnical and geophysical studies can identify regions that are susceptible to enhanced shaking or liquefaction. These studies produce maps that are used by engineers and architects to reduce damage to structures from earthquakes, and help emergency managers improve the accuracy of earthquake disaster computer simulations.

The State of Idaho BHS has funded the Idaho Geological Survey (IGS) to prepare such maps in several parts of Idaho, including Idaho Falls-Rexburg, metro Boise, Teton County, Pocatello, and Sun Valley. The maps and the data used to make them are available in digital format for free download at the website of the Idaho Geological Survey (http://www.idahogeology.org/). Two types of maps have been produced: NERHP Site Class Maps and Liquefaction Susceptibility Maps.

Vs30 Analysis Methods

NERHP Site Class Mapping

In 1997, the National Earthquake Hazards Reduction Program (NEHRP) established procedures for placing building sites into classes based upon the geotechnical properties of near-surface materials. For each NEHRP site class, coefficients adjust expected earthquake motions for local ground conditions. Earthquake ground motion parameters are generated by USGS for all parts of the United States and are available as national seismic hazard maps (http://earthquake.usgs.gov/hazards/products/). NEHRP site classes are not shown on national seismic hazard maps (NSHM) because local conditions are frequently too variable to accurately depict at the NSHM scale, or because the required geotechnical information is unavailable. Both NEHRP site classes and USGS national seismic hazard maps are incorporated into the International Building Code and International Residential Code.

NEHRP site classes range from A-F, from lowest to highest expected ground motion and potential damage. Several methods were used to classify earth materials in order to prepare the maps. In Idaho Falls-Rexburg and metro Boise, geotechnical properties of near-surface materials measured during construction projects were compiled and correlated with geologic map units. In Teton County, Pocatello, and the Sun Valley area, measurements of shallow shear-wave velocities (Vs30) were made. Both methods yield useful results but Vs30 data are preferred because they permit direct calculation of NEHRP site classes.

Methods used in Pocatello are typical of Vs30 surveys. After obtaining permission from land owners, a 40 kg (88 lb) weight was dropped repeatedly on the ground to generate shallow seismic waves.

Geophones connected to a 100 m (330 ft) long cable recorded the waves and transmitted them to a laptop computer for processing and computation of Vs30. The surveys do not damage property or vegetation. Vs30 was determined at 51 sites within Pocatello city limits, correlated with type and thickness of surficial geologic deposits in Pocatello, and used to produce a NEHRP site class map.

Liquefaction Susceptibility Mapping

In order to determine the hazard posed to an area by liquefaction, two types of data are collected. First, geological and agricultural soil maps are used to outline areas underlain by bedrock or firm, consolidated deposits where liquefaction cannot occur. The maps, along with water well drilling logs, are further studied to identify regions with evidence for sandy, cohesionless materials. Such deposits can experience liquefaction during a strong earthquake if saturated. Second, data from water wells and agricultural soil maps are collected to identify areas subject to saturation by high water tables. It is fairly common in Idaho for saturation to occur at least seasonally as a result of spring run-off or irrigation practices. The two types of data are combined to produce maps showing High, Medium, or Low liquefaction hazards. High hazard areas possess both sandy, cohesionless materials and evidence for at least seasonal saturation. Medium hazard areas contain sandy, cohesionless materials but water tables are greater than 12 m (39 ft) below the ground surface. Low hazard areas are underlain by bedrock or cohesive materials than cannot liquefact.

Summary of Results from Mapping

In all areas mapped, the most common NEHRP site class was C (very dense soil and soft rock). All maps contained smaller regions of site class D (stiff soil) and even smaller areas of site class E (soft soil). Class D and E sites were generally located in or adjacent to wetlands along rivers.

Liquefaction susceptibility hazard was generally low in most populated regions. For example, Idaho Falls and substantial portions of metro Boise are largely built on well-drained, gravelly soils or areas of shallow bedrock. However, some developed regions of the Rexburg area and Teton County have potentially cohesionless deposits and high water tables.

A notable finding is that the IGS mapping generally reduced hazard assessments when compared with the automated method used by USGS to estimate NERHP site class from topography. This is because low relief land surfaces may be assigned relatively high hazard (site class D) by the USGS because they are assumed to contain thick unconsolidated deposits. While true in many places elsewhere in the United States, in Idaho such land surfaces are often underlain by shallow volcanic rocks.

Hazus Analysis

Because a single earthquake will not result in statewide damage, the most appropriate risk assessment methodology was to conduct scenario modeling using FEMA's Hazus 2.1 loss estimation software. The Hazus tool is very useful in mitigation planning, because it provides an acceptable means of forecasting earthquake damage, loss of function of infrastructure, and casualties, among many other factors. There are three levels of HAZUS, from Level 1, which uses the default FEMA-derived datasets and damage functions, to Level 3, which uses independently compiled, incredibly huge, and accurately verified structure and infrastructure inventories.

For the 2013 Plan analysis, Hazus Level 2 assessments were performed. Enhanced data inputs were leveraged from a number of sources that allowed for improved loss estimation and analysis including:

- Improved state-wide inventory data provided by IDWR. This included facility and infrastructure data covering: essential facilities, high potential loss facilities, rail, transportation, and utilities. IDWR performed both spatial and attributes updates to the Level 1 facility data that is provided with Hazus.
- Locally jurisdictional facility information provided by ICRMP. This included ~8,500 structures that were geolocated. Structure data included both structure and content valuations.
- Updated 2010 Census data in a Hazus-compliant database schema provided by FEMA. This data included demographic and building stock updates based upon the 2010 Censes, that are not yet available in Hazus 2.1.
- Seismic site survey data from the IGS. This included newly available data from surveys conducted in the Boise, Idaho Falls, Pocatello, and Teton areas. Data included liquefaction susceptibility and NEHRP site classifications.

The Hazus analysis conducted in 2010 was limited to Level 1 assessments, due to a lack of the types of data inputs documented above. In both 2013 and 2010, three regions of the State were processed using Hazus and a statewide Hazus study region was created for each. The three hazard scenarios that were analyzed included:

- 7.0-magnitude event in the City of Boise
- 7.0-magnitude event in the City of Idaho Falls
- 7.0-magnitude event in the City of Pocatello*/**

*** It is important to note that areas around Pocatello include the Idaho National Laboratory (INL), a Federal nuclear installation with several classified facilities. The data for that area is not included in the loss estimate presented below.**

**** The 2010 analysis was centered in Idaho Falls. It was decided in 2013 to change this location approximately 50 miles SW to Pocatello, due to the IGS survey data being acquired there.**

For each scenario in 2013, two separate Hazus assessments were performed. One was specifically designed to utilize the IDWR and FEMA enhanced data sets, the other to leverage the ICRMP enhanced data sets. All assessments were able to utilize all IGS survey data.

The results of the loss estimations performed using the IDWR/FEMA data are summarized below in Table 3.5.G. Information reported includes the expected: numbers of buildings damaged, numbers of buildings completely damaged, building losses (structure & contents), business interruption losses, total direct economic losses, and a casualty estimate. Maps 3.5.O-3.5.Q at the end of the chapter also show the total direct economic loss estimations, per census tract, for the 3 scenarios. Direct economic losses include all building losses, business interruption losses, as well as all transportation and utility system losses.

The expected losses present a range of estimates to use for planning for a seismic event of this magnitude. Depending on the population of the area impacted, expected total direct economic losses could range from $2-$7 billion. Structure damages are expected for between 30,000 – 100,000 buildings, with complete damage to 2,000-5,000 of them. Probably the most important estimates to observe are the casualty estimates, which for these 3 scenarios ranged from 100-300+ citizens.

TABLE 3.5.G: Expected Damage and Loss Estimates, Arbitrary 7.0 Magnitude Earthquake Event

Scenario	Building Damage (# of Structures)	'Complete' Building Damage (# of Structures)	Direct Building Loss ($M)	Business Interruption Loss ($M)	Total Direct Economic Loss* ($M)	2 PM Casualty Estimate
Boise 7.0	107,318	5,412	$5,374	$1,446	$7,344	323
Idaho Falls 7.0	48,140	2,938	$2,233	$608	$3,211	196
Pocatello 7.0	32,062	2,058	$1,509	$419	$2,138	94

Note: The total direct economic loss estimates include all direct building and business interruption related losses as well as all lifeline (transportation and utility systems) related losses

The results of the loss estimations performed using the ICRMP data are included below in Table 3.5.H. It should be noted that this 'User Defined' Hazus analysis was only utilizing the local jurisdictional facilities provided by ICRMP, with no other building stock or populations being analyzed. Data summarized includes the expected: numbers of buildings damaged, numbers of buildings whose damage exceeds 'moderate' (these buildings have at least a 50% chance of this occurring), numbers of buildings whose damage exceeds 'extensive' (these buildings have at least a 50% chance of this occurring), and total building loss.

The expected losses offer an additional range of estimates to use for planning for a seismic event of this magnitude. Depending on the location of the seismic event, expected local jurisdictional facilities could see direct building losses in the range of $100-$200 million. Damaged structures would be expected to total between 4,000-6,000 local facilities. Of those, a few hundred would be moderately or extensively damaged.

TABLE 3.5.H: Expected Damage and Loss Estimates, Arbitrary 7.0 Magnitude Earthquake Event (User Defined)				
Scenario	Building Damage (# of Structures)	Number of Buildings with at Least a 50% Chance of Exceeding Moderate Damage	Number of Buildings with at Least a 50% Chance of Exceeding Extensive Damage	Direct Building Loss ($M)
Boise 7.0	5,688	312	133	$186
Idaho Falls 7.0	4,028	360	208	$154
Pocatello 7.0	4,705	323	268	$110

Note: User-defined inventory consisted of 8,437 structures – the above numbers are derived from that total

Further analysis conducted as part of the 2013 Plan update was to compare the results of the 2013 Level 2 assessments with the Level 1 assessments conducted in 2010. The goal of this analysis was to attempt to better understand the accuracy of both the Level 2 and Level 1 analysis. When comparing these loss estimations, it is important to take into account any variables. The most notable of which include the Level 2 data inputs detailed above, as well as the fact that different Hazus software versions (2.1 versus MR4) were used.

Loss estimates from the Hazus produced global summary reports for both the 2013 and 2010 assessments are included in Table 3.5.I below. The change that was calculated between the 2013 and 2010 analysis is also shown. Data summarized for each scenario included:

- Expected building damage (number of structures)
- Expected 'complete' building damage (number of structures)
- Expected building loss estimates ($)
- Expected business interruption Loss Estimate ($)

TABLE 3.5.I

Scenario	Expected Building Damage (# of Structures)		Expected 'Complete' Building Damage (# of Structures)		Expected Building Loss Estimates ($ Millions)		Expected Business Interruption Loss Estimate ($ Millions)	
Boise 7.0	107,318	+44%	5,412	+65%	$5,374	+98%	$1,446	+71%
	74,469		*3,288*		*$2,714*		*$844*	
Idaho Falls 7.0*	48,140	+55%	2,938	+90%	$2,233	+94%	$608	+78%
	31,151		*1,549*		*$1,152*		*$341*	
Pocatello 7.0**	32,062	+>100%	2,058	+>100%	$1,509	+>100%	$419	+>100%
	4,347		*25*		*$36*		*$10*	

Note: 2010 results are shown in italics

***2010 analysis was based on a 6.9 magnitude event**
****2010 analysis epicenter was located in Soda Springs**

What stands out the most between the 2013 and 2010 loss estimations is that increases were seen across the board. Provided below are comments on each of the specific scenarios and data inputs, including possible explanations for the results that were obtained. It is not possible to simply equate these increases to improvements in the loss estimations without some additional reflection.

The Boise scenario had the fewest variables to contemplate, but there are still a lot of things to consider when reviewing the resulting loss estimations. Losses ranged from an increase of 44% to an increase of 98%. The data most likely driving these increases was the 2010 Census information. The reason for this is that the Boise area experienced drastic growth between 2000 and 2010, with Ada County's population increasing by 30%. So, one would expect losses to increase similar to that growth rate. It can be safely said that the improved Census information helped arrive at a more accurate loss estimate.

The improved Hazus inventory data provided by IDWR surely also played a role in the higher estimations, as that data included more a detailed inventory (number of structures), in addition to some updated structure valuations. These building valuations were most likely higher than the assumed values that Hazus utilized in the MR4 version of its data, which is what drove the 2010 results. As with the Census data, it can be also said that the improved IDWR building stock information allowed for improved loss estimates.

Initially, it was not entirely clear if the enhanced IGL survey data influenced the results one way or another. To answer this question, the 2013 Boise scenario was rerun without the IGL inputs, defaulting to the standard Hazus survey inputs. Surprisingly, the loss estimates performed without the IGL data were 12-21% higher. This confirms that the IGL inputs do result in more accurate loss estimations, as the default Hazus survey inputs assume soil types that are more conductive to structural damages.

The last remaining variable is the Hazus software itself. Unfortunately, it is not possible to quantify how updates to the software may have influenced the loss estimations, but it is assumed that any changes that were made were aimed at improving the quality of the loss estimations.

The Idaho Falls scenario had one additional variable not encountered with the Boise analysis. That is the fact that the magnitude used for the analysis was 6.9 in 2010 and 7.0 in 2013. Although this seems minor, it should be noted that magnitudes are a logarithmic scale. Thusly, the difference of 0.1, between 6.9 and 7.0, means a ~41% increase in energy yield. So it can be assumed that some of the increases were caused by this seemingly minor change. With that pointed out, increases for this scenario ranged from 55% - 94%. Similar to Boise, the population around Idaho Falls grew 26%. These 2 facts, along with the others mentioned above for Boise seem to confirm that these Level 2 Hazus loss estimates provide better planning information.

The Pocatello scenario saw the largest changes across the board, sometimes by orders of magnitude. This is mostly caused by the fact that the epicenter of this scenario was moved from its 2010 location in Soda Springs. The reason for this was to better utilize the IGL data available in Pocatello.

In the end, it is believed that the 2013 Level 2 Hazus analysis and resulting loss estimations are a more accurate depiction of the losses that could be expected should similar events occur. As is usually the case, improved data inputs drive improved analysis, resulting in an improved assessment.

Local Hazard Mitigation Plan Vulnerability Assessments

All 47 of the State's local hazard mitigation plans were analyzed for use in the State's hazard mitigation plan update. Certain sections of the plans were then collected into a central database that allowed for further analysis. These data were summarized, and some of those results are provided below.
Map 3.5.R, at the end of this section, highlights the eight local plans that identified earthquake as one of their significant hazards. For these jurisdictions that would be considered the most vulnerable to this hazard (based on their own prioritization), Table 3.5.J summarizes the number of structures impacted by the earthquake hazard and the corresponding loss estimate.

Since the 2010 Plan update, three additional jurisdictions have added earthquake as one of their top-three hazards. This is a positive sign from the State's perspective, as earthquake outreach and education efforts were one of the actions identified during the 2010 Plan update. History has proven that is it sometimes difficult for people to perceive their risk to hazards that do not occur on a damaging scale very frequently. These types of advances in regards to public perception of earthquake risk are important to note.

By comparing Maps 3.5.M, 3.5.N, and 3.5.R, it is still apparent that seismic outreach and education are needed in other areas of the State. Sometimes however, from a local perspective, it is the high probability, low impact events that they chose to focus on. This can be the result of local decisions to direct their limited resources to the hazards they can realistically focus on.

TABLE 3.5.J:
Local Hazard Mitigation Plan Roll-Up, Jurisdictions Ranking Earthquake as a Significant Hazard

Local Plan Name	Earthquake Ranked as Significant	Structures in Hazard Area	Loss Estimate
Ada	X	133,361	$8,894,509
Adams			
Bannock	X	25,000	$18,410,000
Bear Lake			
Benewah			
Bingham			
Blaine			
Boise			
Bonner			
Bonneville			
Boundary			
Butte			
Camas			
Canyon	X	5,941	$890,325,375
Caribou	X		
Cassia			
Clark			
Clearwater			
Custer			
Duck Valley Reservation			
Elmore			
Franklin	X	3,000	$4,090,000
Fremont			
Gem			
Gooding			
Idaho			
Jefferson			
Jerome			
Kootenai			
Latah			
Lemhi			

TABLE 3.5.J:
Local Hazard Mitigation Plan Roll-Up, Jurisdictions Ranking Earthquake as a Significant Hazard

Local Plan Name	Earthquake Ranked as Significant	Structures in Hazard Area	Loss Estimate
Lewis			
Lincoln			
Madison			
Minidoka			
Nez Perce			
Nez Perce Tribe			
Oneida	X	34	$1,680,000
Owyhee			
Payette			
Power			
Shoshone			
Shoshone-Bannock Tribe	X		
Teton	X	170	$5,090,000
Twin Falls			
Valley			
Washington			

Source: Local Hazard Mitigation Plans

Consequence Analysis Scenario

Another way vulnerability was assessed was by conducting a consequence scenario that analyzed a hypothetical hazard event. The Seismic Technical Advisory Group (TAG) met on October 23, 2012 to analyze an earthquake scenario involving a 6.9 Mw event in Pocatello. The event discussed occurred in the fall months, at 8:00 AM in the morning.

The Seismic TAG walked through this group exercise, where they scored, from 0 (no consequences) to 5 (most severe consequences]), the short-term (0-6 month) and long-term (6+ months) consequences of the scenario as it pertained to the following systems:

- The public
- First responders
- Continuity of operations
- Property, facilities, and infrastructure
- Economic conditions
- Public confidence in government
- The environment

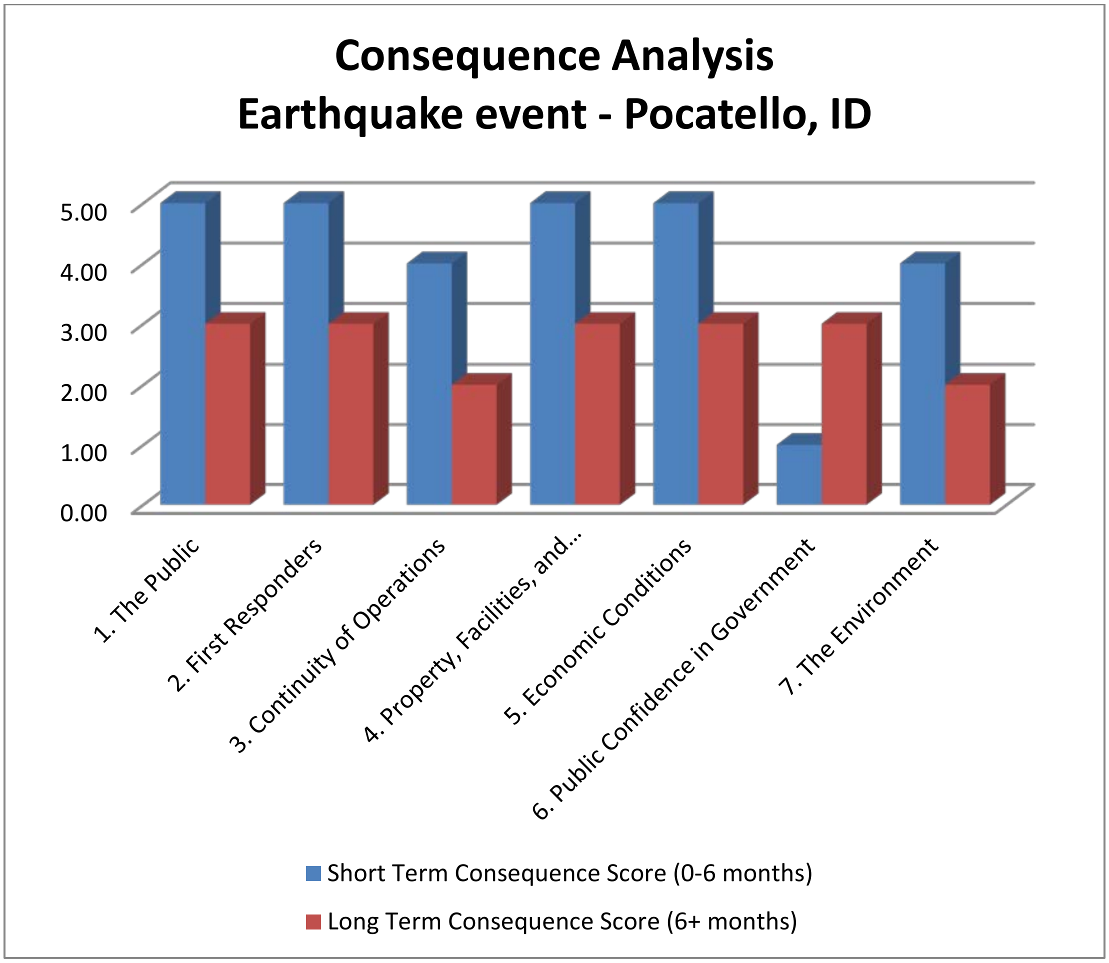


Figure 3.5.K: Consequence Analysis Earthquake

The chart above (Figure 3.5.K) presents the results of the exercise. Looking at the short-term consequences of this 6.9 Mw event, the TAG felt that the most severe consequences would be felt by the public, first responders, the built environment, and the economy. The group felt that the public's confidence in the government would be barely impacted in the early day/months after the disaster would occur. From a long-term standpoint, a definite shift is seen on the consequences to the various systems discussed. The TAG felt that equally moderate consequences would be felt by a majority of the systems, with the impacts to continuity of operations and the environment fairing a little better. Overall, it was determined that the short-term impacts of a large seismic event would be greater than the long-term effects.

Some observations of the group to note included:

- The fact that this hypothetical event occurred in the fall would delay improvements to the built environment as most reconstruction would be hampered by the winter weather.

- Federal assistance in the months and years following the event would assist and benefit a number of these systems in the long-term.
- Conversely, the bureaucracy that would follow the Federal assistance could negatively affect the public's confidence in the government in the long-term.

In addition to the ranking exercise, the TAG discussed additional questions pertaining to the scenario, including:

- Would the season and timing of when the event occurred alter any of these consequences?
- What other hazards could be triggered by this initial event?
- Would any regional impacts result from this event?
- Have any changes sincere the last plan update altered any these consequences?

Some of the comments and discussions that were raised included:

- If this event would occur at a different time of the year, the consequences could be more severe. Examples included whether reservoirs would be filled and how that might affect the agricultural segment.
- Improvements in seismic data, based on recent studies conducted by the IGL, have helped to improve seismic knowledge and risk assessments in the State.
- Recent disasters in the State have shown an improvement in regional networking for responders.

The results of a similar exercise conducted as part of the 2010 Plan update are included below in Figure 3.5.L. Overall, similar trends were observed for the various systems, with the exception of public confidence in the government as was pointed out above. The public, first responders, and economic conditions all stood out as being the systems most affected.

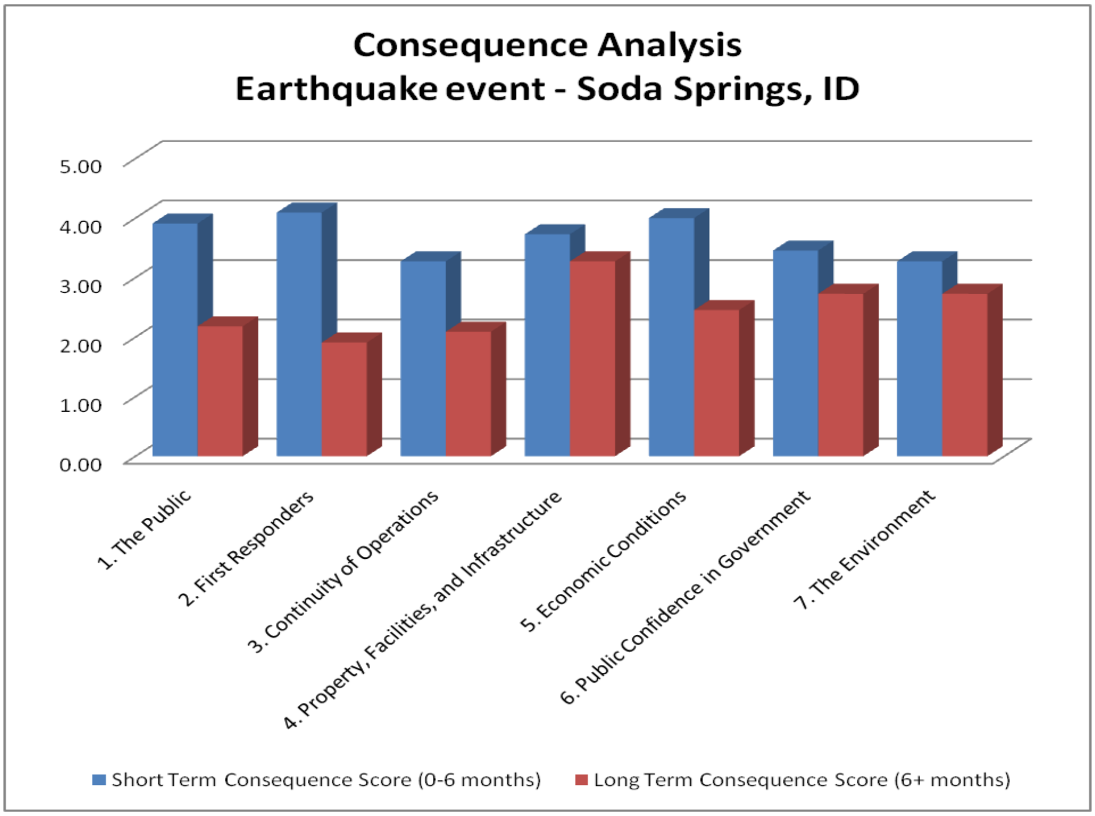


Figure 3.5.L: Consequence Analysis Earthquake

MITIGATION RATIONALE

While few local plans prioritize earthquake as a major hazard, the significant economic impact of an earthquake makes mitigation a priority. The 6.9-magnitude scenario in Idaho Falls, for example, resulted in $1.5 billion in damages, which would be truly catastrophic. A considerable number of public and private commercial buildings are pre-code structures, constructed of both reinforced and unreinforced masonry. Much of Idaho's housing stock in suburban and rural communities was built prior to the 1970s, before building codes were in force. Additionally, rural Idaho communities do not have the resources to respond to widespread damage that might be caused by a catastrophic earthquake. Earthquakes are one of the State's least predictable and most poorly understood hazards.

What is the largest earthquake Idaho has ever had and where was it, and how soon can you predict an earthquake?

Scott Dorval, Channel 6 Chief Meteorologist, answered this question posed by a Liberty Elementary school student. You can track where earthquakes are occurring at Idaho 6 on Your Side. Typically, there are many tiny earthquakes going on in the mountains. The 1983 Borah Peak Earthquake measured 6.9 and was the strongest to occur in Idaho. It caused some major damage in Mackay and Challis and was felt in Boise. During a quake, two plates that are being held together because of friction, suddenly overcome that friction with one plate popping up higher than the other. The earthquake left a scarp line shown here displacing the ground up to seven feet. "There were reports of some people out hunting nearby and the ground started to shake and the pickup was literally bouncing off the ground like you would see in a cartoon. One person reported even seeing what you call a zipper when you see a line shooting right across the ground here. Finally the ground dropped just below the pickup truck and then the truck fell down on top of it." Borah Peak rose nearly 7 feet in elevation. (Dorval, 2013)

GENERAL MITIGATION APPROACHES

Information/Outreach and Public Education

Much mitigation work (such as home retrofitting and non-structural falling hazard reduction) is dependent on the actions of property owners and residents. Hazard awareness and education programs must lay the groundwork of knowledge that leads to this work.

BHS funds cooperative projects with the Idaho Geological Survey (IGS) on an annual basis. These projects have included summer field workshops for Idaho's earth science teachers, the development of NEHERP soil classification and liquefaction susceptibility maps, and the development of public education materials on geologic hazards. This outreach is funded using a variety of grant programs, including the Earthquake Hazard Reduction Grant, Emergency Management Performance Grant, and Pre-disaster Mitigation Planning funds. The earth science teacher workshops have been held for the past 20 years, facilitated by the IGS. The focus of the workshops is on the science of natural hazards, hazard mitigation strategies, disaster preparedness for schools, and the enhancement of science teaching. As a result of the workshops, teachers are improving the study of seismic safety in their schools, and the next generation of decision makers in Idaho is growing up better educated to seismic risks and other natural hazards. The facilitators of the workshops are constantly seeking new audiences. The booklet mentioned above, "Putting Down Roots in Earthquake Country", was published using mitigation grant monies by BHS, with considerable input and valuable advice from the IGS, and was widely distributed in eastern Idaho. The booklet was especially well received by educators in many parts of the State. It will be distributed at every opportunity, through every possible venue.

Infrastructure

New public facilities and other infrastructure must be built to earthquake-resistant standards. The large stock of buildings constructed before 1992 is more problematic. Changes in occupancy, such as occurs when old buildings are converted to restaurants, shops, and apartments, provide opportunities for seismic retrofits. Extensive work is expensive, though, and hard to justify to building owners. Lifelines and critical facilities should not be concentrated in high-risk areas. Mitigation projects will be identified in separate categories, as follows:

- Public infrastructure
- State/county facilities
- Private infrastructure

Regulatory

Enacting building codes, dam design requirements, and other regulatory measures is necessary to ensure that structures have earthquake-resistant construction. Areas of known extreme hazard, such as fill soils and known faults, can be designated and zoned for open space or similar non-vulnerable uses. BHS adopts the Western States Seismic Policy Council (WSSPC) Policy Recommendation 07-4 wherein WSSPC not only endorses adoption and enforcement of International Existing Building Code, the International Building Code, and the International Residential Code, but also discourages modification and amendments that weaken these codes. Further BHS adopts the additional policy of encouraging including of NEHRP provisions which include purpose, education, incentives, lifelines, and public and private sectors.

The State could also provide incentives (e.g., tax relief) for proper owners to retrofit their homes and other properties. Insurance is typically very expensive, and coverage is generally not required by lending institutions.

In addition, BHS adopts WSSPC Policy Recommendation 06-1: Developing Earthquake Risk-Reduction Strategies stated here:

WSSPC strongly encourages the development of long-term, comprehensive statewide and community - level earthquake risk-reduction strategies as part of an all-hazards plan to reduce injury, loss of life, property damage, and economic disruption from earthquakes.

WSSPC believes comprehensive statewide and local plans and strategies should include the following elements:

- Assessment of all seismic hazards to quantify and define the risk to communities;
- Implementation of land-use and development policies to reduce exposure to earthquake hazards;
- Adoption of enforcement of the International Building Codes for the seismic design, inspection, and construction of new buildings and structures;
- Adoption of International Existing Building Code for the maintenance and retrofit of seismically "at risk" structures;
- Development and implementation of retrofit, redevelopment, grant and abatement programs to help strengthen existing structures, where necessary;

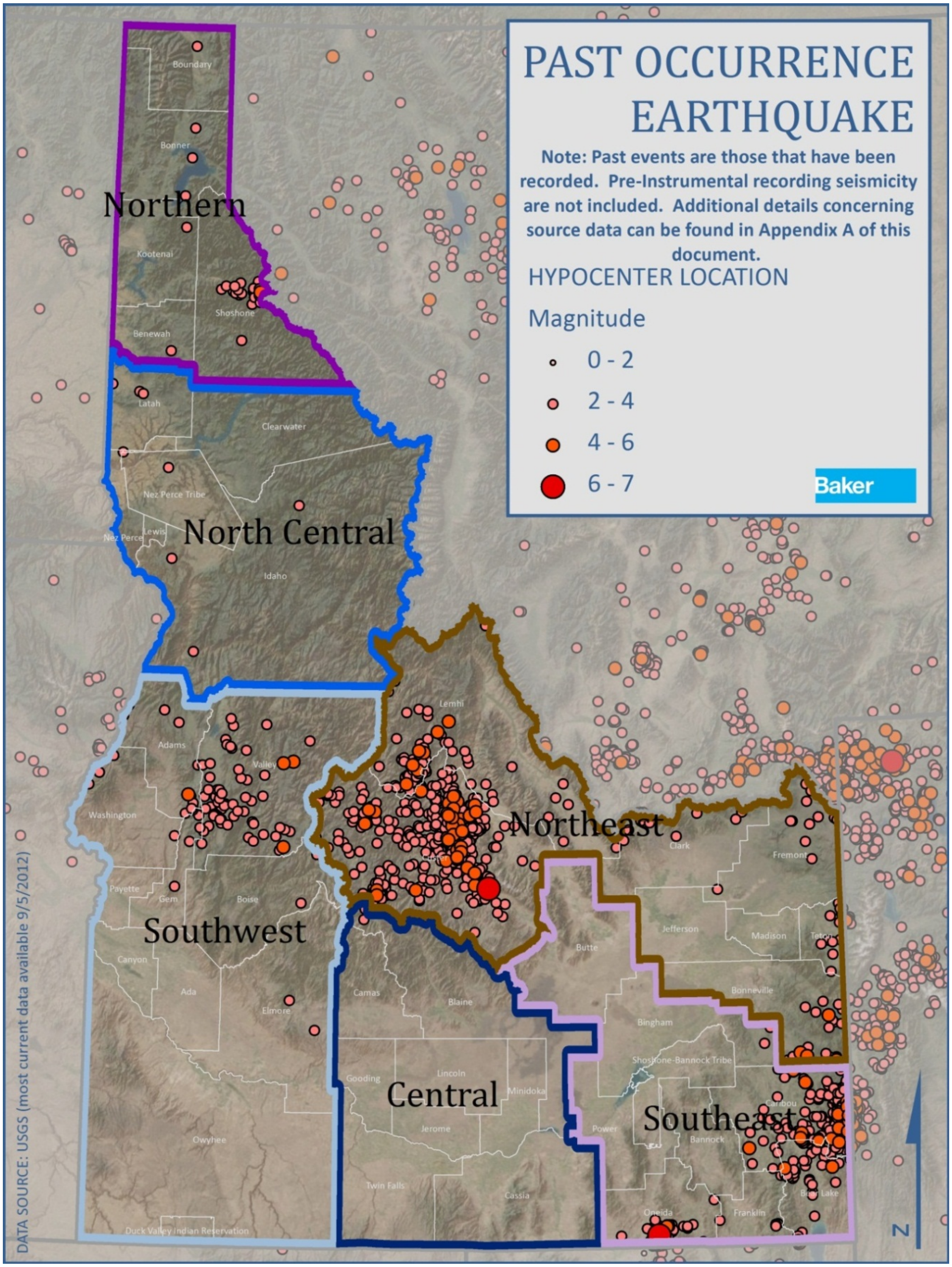
- Support of [ongoing] public-education efforts and public/private partnerships to raise awareness of seismically induced threats and build constituent support for earthquake hazard reduction programs.

Mapping/Analysis/Planning

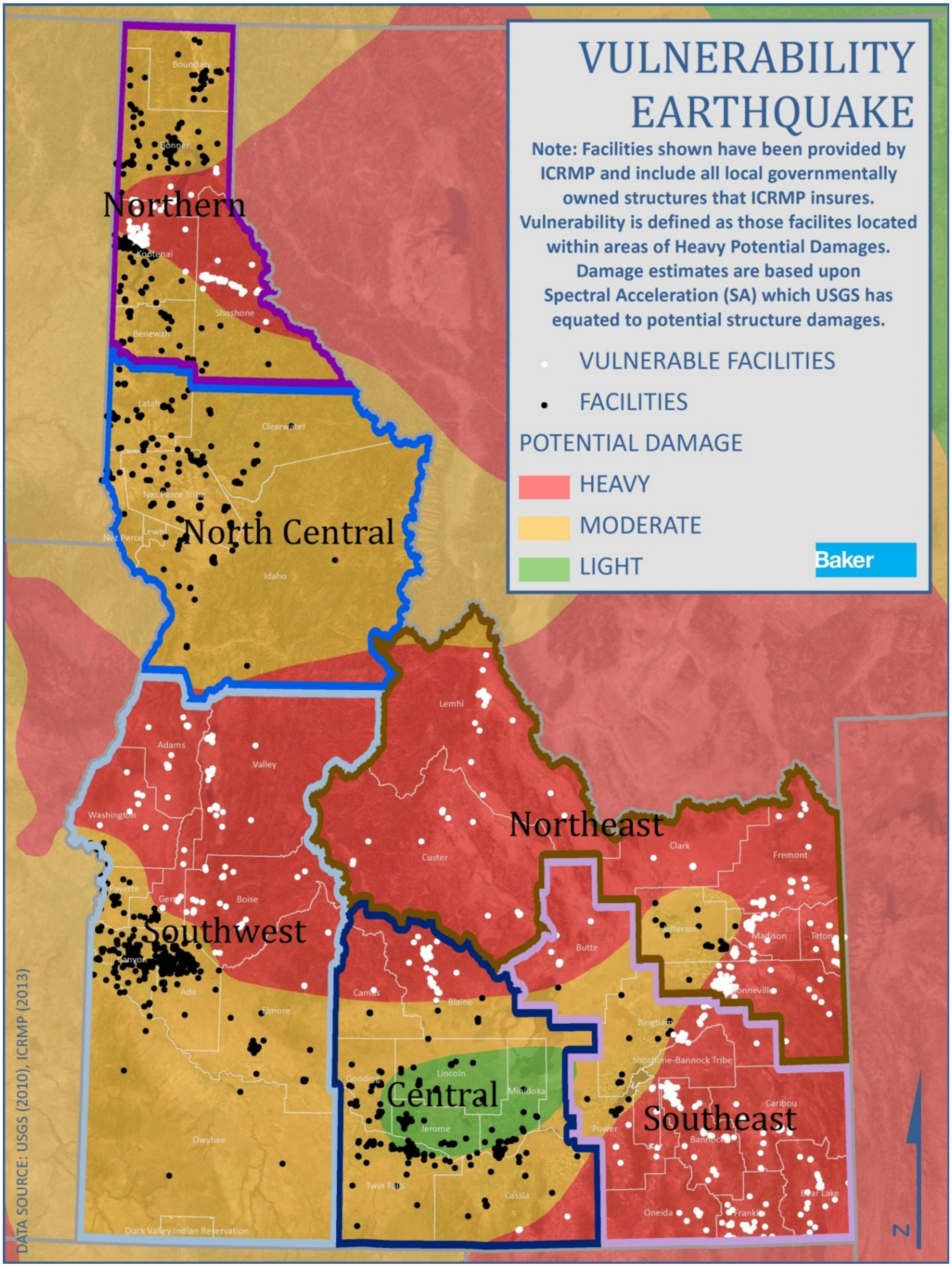
An accurate understanding of a hazard is the first step towards successful mitigation. To fully understand a hazard and the risk that it poses, the ability to accurately assess vulnerability is vital. After vulnerability is determined, it is then possible to assess potential losses if a state inventory of facilities and infrastructure is available.

At the time of the 2013 Plan update, major advances in the availability of various data inputs allowed for an improved vulnerability and loss assessment to be performed. Continued refinement of both vulnerability and inventory data will enable for continued refinements in the risk assessment process.

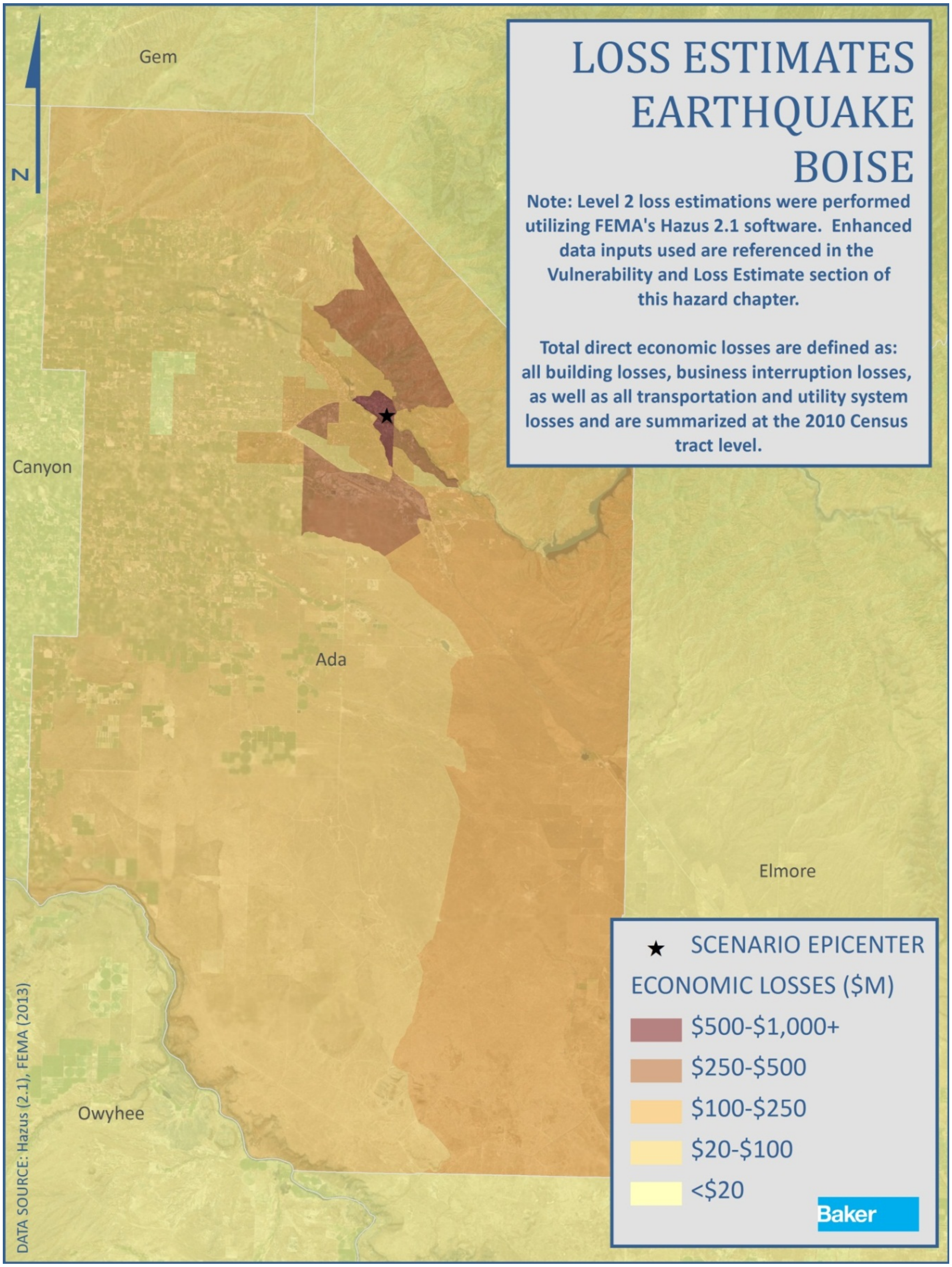
Source: ThinkStock.com



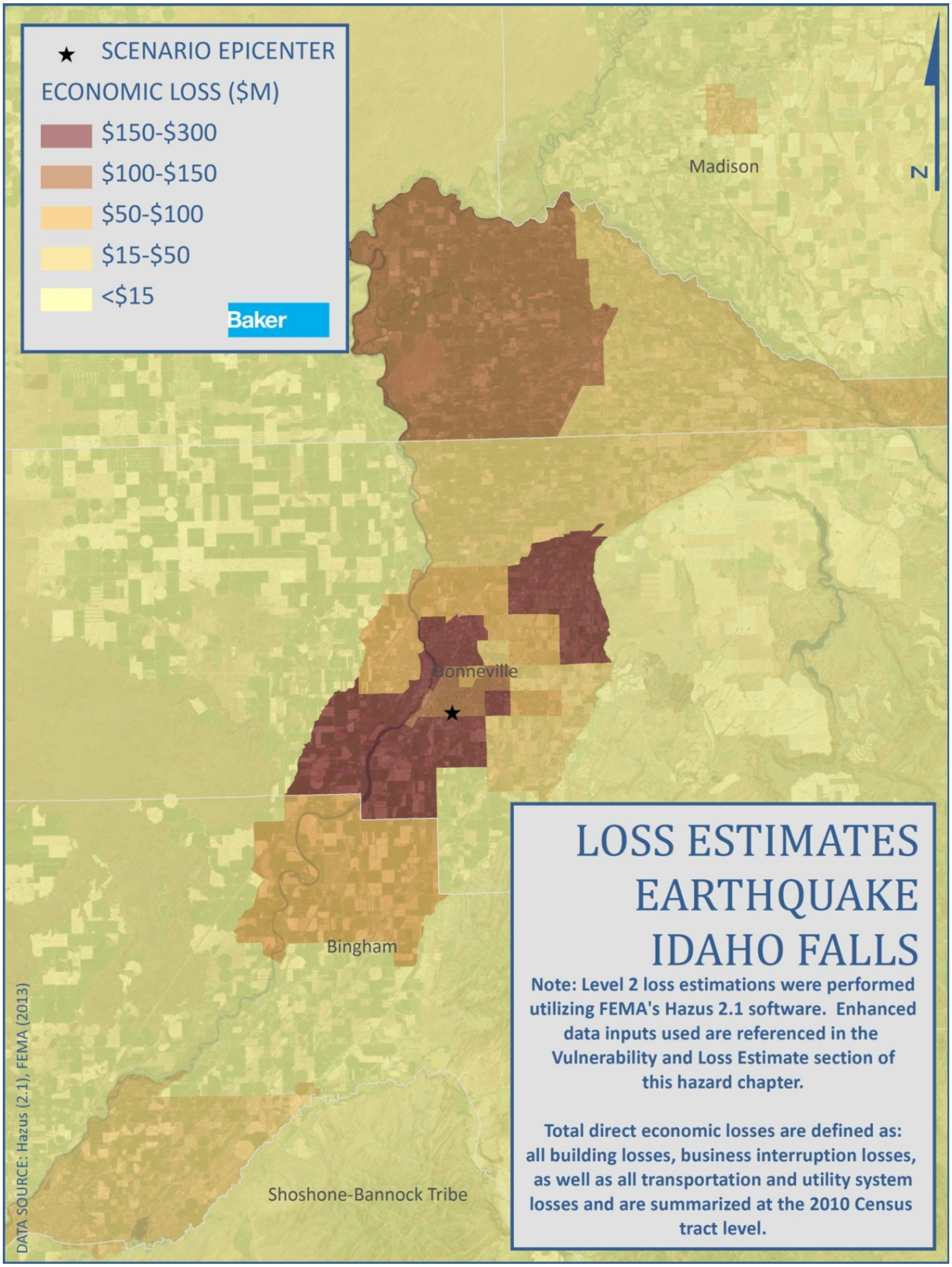
Map 3.5.M: Past Earthquake Occurrences (Note: Pre-instrumental recording seismicity are not included)



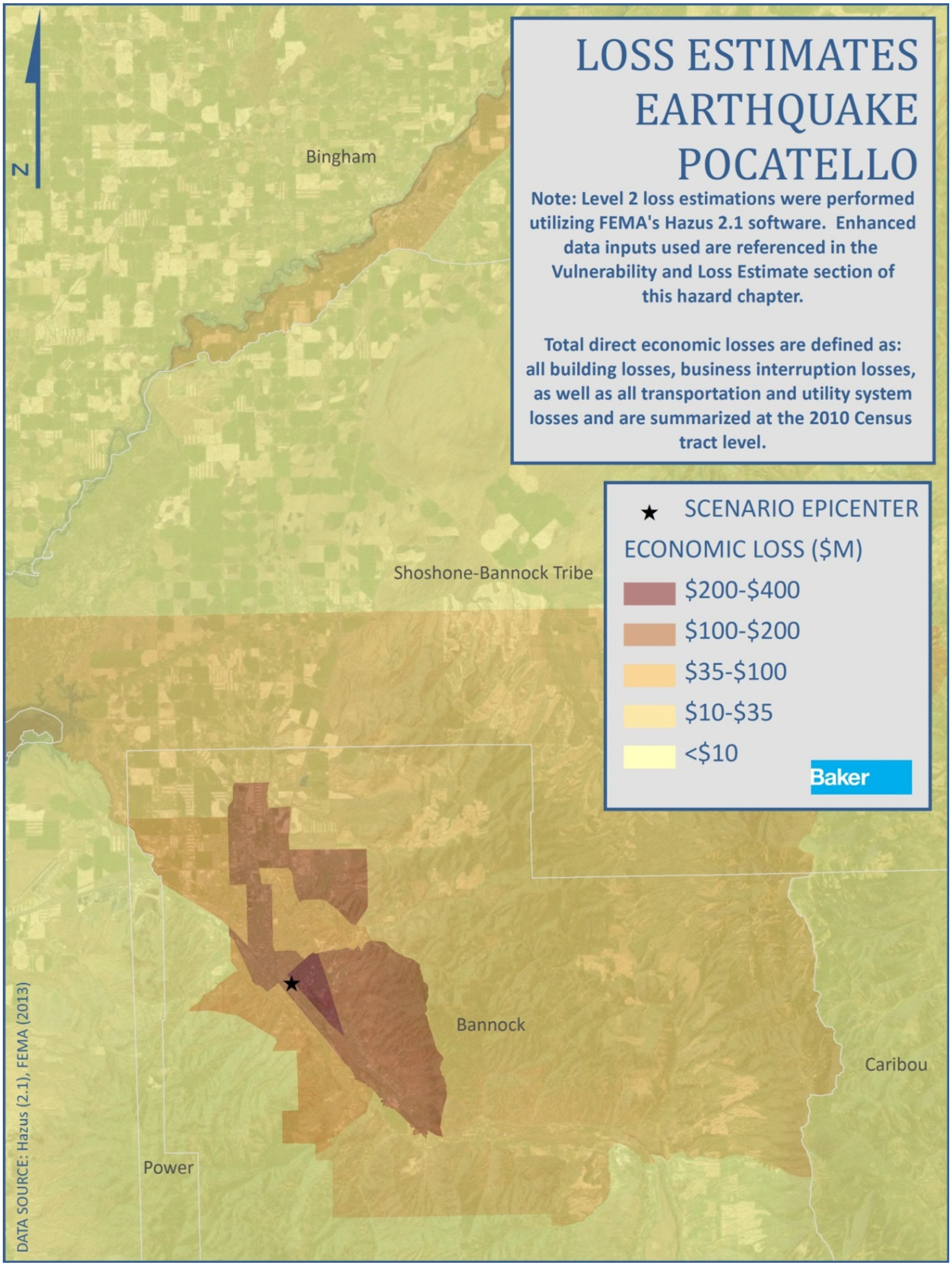
Map 3.5.N: Earthquake Vulnerability



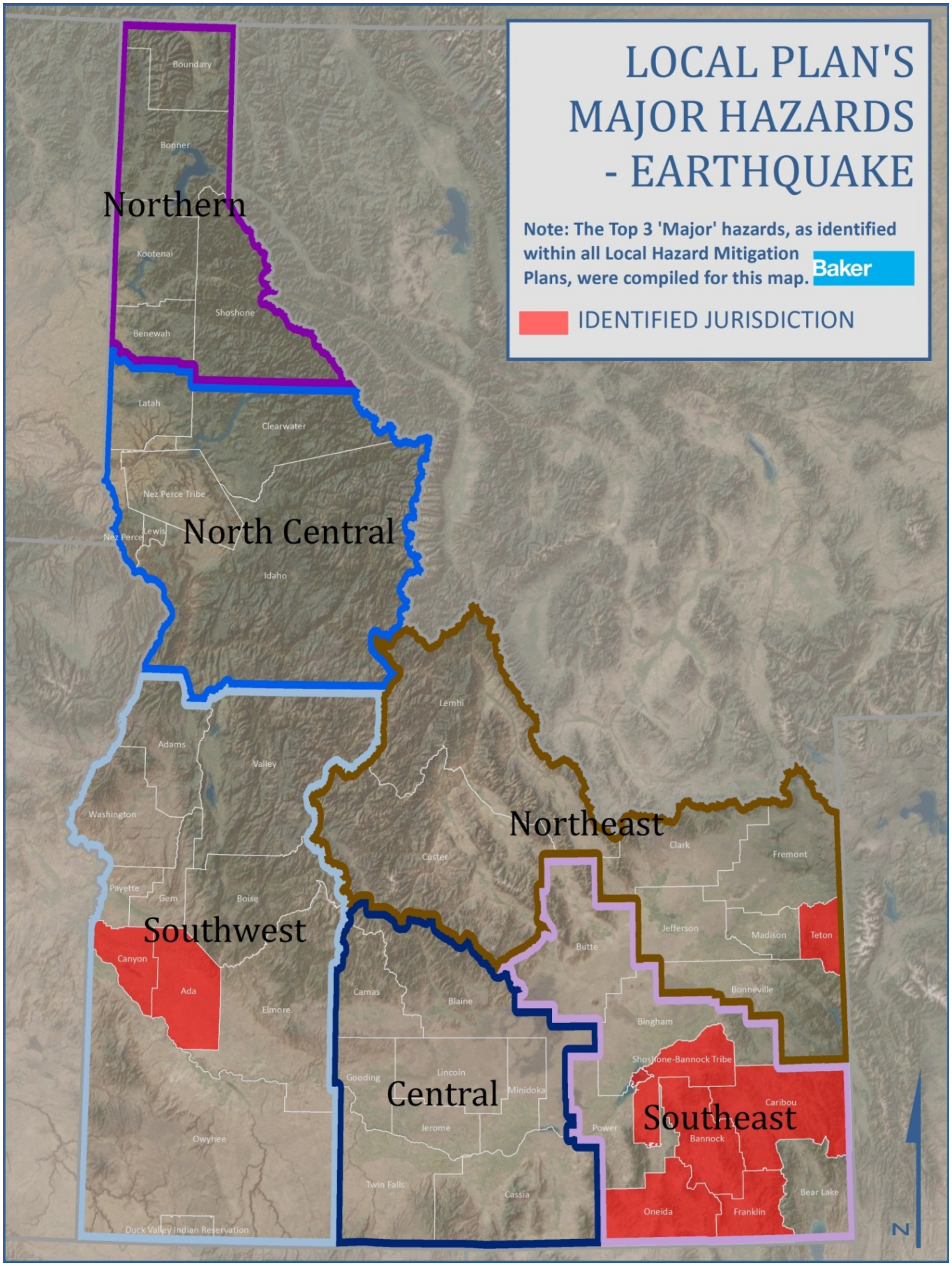
Map 3.5.O: Earthquake Hazus Loss Estimation - Boise



Map 3.5.P: Earthquake Hazus Loss Estimation – Idaho Falls



Map 3.5.Q: Earthquake Hazus Loss Estimation – Pocatello



Map 3.5.R: Earthquake Identified as Local Plan Major Hazard